RADC-TN-61-143

CENTRE DE PHYSIQUE ÉLECTRONIQUE ET CORPUSCULAIRE

DOMAINE DE CORBEVILLE par ORSAY (Seine-et-Oise)

TECHNICAL STATUS REPORT N° 8

Period of Report

1.7.1960 through 31.12.1960

-:-:-

HIGH POWER X-BAND BACKWARD WAVE OSCILLATOR TUBE

-:-:-

Contract N° AF 61(052) 68

31 December 1960

176 800

-:-:-

"The research reported in this document has been sponsored by Rome Air Development Center of the AIR RESEARCH AND DEVELOPMENT COMMAND, UNITED STATES AIR FORCE, through its European Office. This report is intended only for the internal management uses of the Contractor and the Air Force."

95.041
W.R. 636

J. NALOT and P. PEIRONET

Compagnie générale de télégraphie Sans Fil
Société Anonyme au Capital de 40.608.900 Nouveaux Francs — Siège Social : 79, Bd HAUSSMANN - PARIS-8e - ANJ. 84-60

W.R. 636

CONTENTS

-:-:-:-:-

SUMMARY

The experimental results on the tubes equipped with four interdigital lines mounted in parallel have not been satisfactory. These negative results are thought to be due to the existence of several parasitic modes.

Therefore the mounting of new tubes of that type has been given up and the efforts have been directed unto the following problems.

a - Complementary tests on interdigital lines, essentially centered on propagation and the parasitic modes so as to understand better the behaviour of the circuits mounted in parallel.

b - Study of a new water cooled tube project. It differs basically from the similar project, described in the last report, W.R. 563, by the section and the shape of the fingers. We are led to a tube where the whole of the fingers is cooled, the circuit regularity is optimum, and the general dimensions are smaller. As far as we know, this project seems to make possible the obtention of better performances.

The study of the circuit and of its matching has been done by means of two experimental lines at the scales 3 and 1.

Technological tests concerning this project are finished. Two tubes have been started; their parts are being machined, and one of them is being mounted.

.../...

We have also achieved the following work :

- Linear tube : a project is being studied, based on the use of a new gun type.

- General studies on the lines : they have been pursued with complementary tests on the alternated finger line, and research work on a new oblique finger line.

-:-:-:-:-:-

DETAILED REPORT

I. TUBES THE CIRCUIT OF WHICH IS COMPOSED OF 4 LINES IN PARALLEL

I.1. General considerations

In the previous report W.R. 563, we established the possibility of obtaining a power in the order of 500 Watts, with a very low efficiency of 10 % and a gain of 3 dB, on a locked-in carcinotron, the circuit of which presents a very high attenuation.

These insufficient results cannot be attributed to the resistivity of the circuit, which is entirely made of copper. On the contrary, it might perhaps be possible to improve slightly the performances of this type of tube by reducing the length of the line so as to realize a compromise between the attenuation of the comb and the starting current of the carcinotron.

Actually, it is probable that the ascertained high frequency facts are due to a complex functioning of the quadruple circuit, characterized by the presence of parasitic propagation modes which appear more easily as the regularity and the input of this circuit are less perfect.

It has been thought illusionary to try and obtain with this tube convenient performances without a more complete knowledge of the propagation on multiple interdigital lines.

The realization of this type of tube has therefore been abandoned for the benefit of the present study.

.../...

I.2. Study of the propagation. Parasitic modes.

This study may be decomposed as follows :

a) identification of the various modes propagated by an assembly of interdigital lines in parallel,

b) research of the causes for which the parasitic modes appear (poor matching of the line, unsymmetrical input, etc...),

c) influence of the coupling between line in parallel,

d) elimination of the parasitic modes.

The first phase of this study was considered once more by carrying out comparative measurements between simple and multiple interdigital line circuits. As it is known, only one mode propagates on a simple line, whereas on a double circuit two modes (a symmetrical and an antisymmetrical) can propagate simultaneously with different velocities. One should therefore find, in the latter case, two neighbouring dispersion curves.

For the time being, the precision of the measurements effected has not permitted to identify with certainty the two modes of propagation.

II. TUBE WITH A WATER COOLED CIRCUIT

Several modifications have been made on the project discussed in the preceding report W.R. 563.

II.1. Principle of the modifications

II.1.1. Finger geometry

The basic idea was the use of a tube bent in U shape, with outer and inner diameters equal respectively to 1 mm and 0.7 mm, but the central part of which was flattened (see Fig.5. of the last report) : thus, while maintaining

.../...

on the circuit a predetermined small pitch, a more important average passage section for the cooling water is obtained. Measurements of the flow rate in function of the pressure have shown later on that a tube with a 0.3 inner diameter was sufficient, as long as water pure enough to prevent risks of obturation is used. It has therefore been finally possible to adopt a constant section tube, for the manufacturing of fingers.

To this fundamental argument, it can be added that

- the machining is made easier
- the circuit regularity is greater
- the coupling resistance of a circular tube is better than that of an ovoid tube.

Let us point out also that two projects have been envisaged on this basis, using in one case shaped fingers, and in the other case trapedoidal shaped, so as to obtain a circuit as regular as possible.

II.1.2. Cooling of the first fingers

In the previous report we indicated some of the main characteristics of the CM 13 R as it had been conceived in the first semester (see general design Fig.8. of report n° 7). In particular, it was said that the three first fingers of the line would not be cooled.

In order to overcome this inconvenience, and for other reasons of technological order, the project has been modified and has led to a device in which all the fingers are touched by the water circulation. This has been made possible by the use of trapezoidal shape fingers.

The general characteristics of this new version of the CM 13 R are given hereafter.

II.2. Circular tube with trapezoidal fingers

This tube is now being realized. For it seems that this version has the maximum guaranties of success when opposed to the difficulties resumed in paragraph II.2.

II.2.1. Study of the circuit

A - Characteristics : the trapezoidal shape fingers are made from a Monel tube, with a 0.6 mm outer diameter. This material has been chosen so as to give the fingers a sufficient rigidity despite their small section. The inconveniency of the poor electric conductivity of Monel is eliminated by a superficial copper-plating, which takes into account the skin effect.

Fig. 1. shows the main geometric characteristics of this circuit. The pitch is of 1.5 mm like in the first CM 13 R version; the total line width passes to 12 mm, the height of the back-plate ridges is brought back to 0.83 mm.

B - Study of the dispersion

a) - 10 cm experimental line (see Fig. 2.)

A line at the scale 3, corresponding to the one described above, but with fingers with a 2.4 mm diameter (0.8 x 3) instead of 1.8, has been used. The length of the fingers, the intervals between the fingers and between the fingers and the back-plate are absolutely homothetic.

The $c/v = f(\lambda)$ curve has been plotted by using the resonance method (Fig. 3).

It will be noticed that the delay ratio goes from 12 to 20 from one extremity of the band to the other.

b) - 3 cm experimental line

The element of the linear circuit on which the measurements have

been effected is in exact conformity with the description of paragraph I.1.1. It has 25 fingers (see Fig. 4).

The dispersion has been measured by the method of the mobile probe.

The curve obtained is given by Fig. 5.

The extreme values of the delay ratio are :

8,000 Mc/s	c/v = 25
10,500 Mc/s	c/v = 14

The very good concordance of the results obtained on the experimental lines at the scales 1 and 3 will be noted, especially as they are not absolutely homothetic.

II.2.2. Transformer

In the previous report (paragraph II.2. page 7), the main details concerning the study of the CM 13 R matching transformer, have been given. The new version makes use of a transformer with identical characteristics; the mismatching caused by the use of a modified line, is corrected very simply by the use of small short-circuits fixed between the first two fingers near their extremities.

This correction has been made directly on the line at the scale 1 (see Fig. 6). On Fig. 7, the matching curve of this line has been plotted. The V.S.W.R. is in the order of 2. Tests are being made to diminish this value.

Photograph 8 A and B show the details of the experimental transformer at the scale 1.

.../...

II.2.3. CM 13 R design project - 2nd version

A - General conception

In the first version of the CM 13 R, described in our previous report, the fingers were threaded and brazed in holes drilled through the cylindrical ring. Further technological tests have shown that the regularity of the drilling was unsatisfactory because of the tendency of the drill to slide obliquely in the metal.

In the new version this difficulty has been overcome by dividing the ring into three elementary rings. The fingers are located in semi-cylindrical slots milled with all the desired precision on the junction walls of the three rings (see Fig. 9).

This technique furthermore allows to make use of trapezoidally shaped fingers which confer to the tube assembly the following advantages :

a - the junction surfaces of the three elementary rings are conical : during the brazing operation the accurate positioning of the assembly is easier to be insured.

b - the spacing between the two extremities of the fingers allows to place within the ring the terminal position of the transformer while ensuring, nonetheless, the cooling of all the fingers.

c - the loss of pressure in the curved portion of the fingers is lower.

The height of the tube has been reduced to 40 mm by modifying the design of the collector and the feeding stem.

.../...

B - Characteristics

Almost all of the characteristics of the first CM 13 R version have been conserved. Yet, the adoption of the Monel tube of 0.6 mm outer diameter for the finger manufacture resulted in a reduction of the height of the back-plate ridges at the extremity thereof to 0.2 mm from the top of the fingers.

Moreover, in reason of their new shape, the fingers have a slightly greater length.

We recall the main characteristics :

- Total number of fingers	91
- Number of attenuated fingers	31
- Finger length	13,6 mm
- Pitch	1.3 mm
- Width of the interaction space	10 mm
- Line - sole distance	1.2 mm

C - General drawing

Fig. 10 is a general drawing of the tube. There will be noticed the simplification of the design of the feeding stem, the reduction of the cross-section of which has permitted to reduce the tube height. There will be also noticed the modifications brought to the transformer assembly.

II.2.4. The state of realization work

A - Technological tests

a) - Copper plating and shaping of the fingers

The Monel tube is coated, by electrolytic deposition, with a 1/100 mm

.../...

thick copper layer. Then the copper is diffused at 800°C during half an hour.

Finally the fingers are shaped on a special steel model.

b) - Brazing

The general assembly project of the tube has foreseen three stages of brazing, the choice of the first alloy being conditioned by the temperature beyond which the superficial copper layer deposited on the Monel risks to be eliminated. Therefore we have foreseen the successive use of :

- Silcoro 75 (Au 75, Cu 20, Ag 5) for the realisation of sub-assemblies (temperature of fusion 890°C)
- Palladium eutectic (Ag 685, Cu 265, Pd 50) for assembling the sub-assemblies together (temperature of fusion 790°C)
- Incosil 15 (In 15, Cu 24, Ag 61) to solder the input finger of the transformer on the first finger of the line

The third stage may optionally be dispensed with by realizing the corresponding operation during the second one.

A trial of brazing the line with Silcoro 75 was not satisfactory. This alloy flows rather badly and it is difficult to insure a perfect tightness on assemblies of parts with fragile contours of the programation, and the temperature controls are not rigorously established. In view of this difficulty, it has been decided to use during the first stage the Pd eutectic, and the Incosil 15 for the grouped second and third stages. A second version CM 13 R tube, now being mounted, will be brazed soon in accordance with this process.

.../...

Jointly, systematic tests will be carried out with Silcoro 75; the use of this alloy may permit, in the definite tube versions, to avoid the use of Incosil 15 which is relatively fragile for receiving the sub-assemblies.

c) - Cooling

The photograph of Fig. 11 shows the line elements which served to study the water circulation and the maximum thermal dissipation of the fingers. The inner diameter of the Monel tube is 0.3 mm. It has been found for an input pressure of 10 Kg/cm^2 and per finger :

flow	....	1.1 cm^3/ sec
speed of flow	....	15.5 m/ sec

The circuit being heated by Joule effect, the fusion of the 10 fingers occured for a total applied power exceeding 4,700 Watts, i.e. 470 Watts per finger.

Assuming that the length of the electron beam is approximately equal to one half of a finger length, and that practically no more electrons impinge on the other half of the line, the line (50 fingers) will be able to dissipate in the thermic form an energy of the order of 10 KW.

This dissipation power is greatly sufficient even if assuming an efficiency of 30 %.

B - Realization

The tubes are being manufactured, most of the components are ready. We may cite in particular : bodies with cooling jacket, line blocks (ring and fingers), sole, collector with cooler, UHF output window, wave guide. Some of these components can be seen in Fig. 9 (rings, fingers) and Fig. 12 (collector, sole).

.../...

The first line block is being mounted, and will be brazed soon. It may be hoped that the first complete tube will be available in the course of January.

II.3. Linear tube

The conception of this tube cas considered when realizing a linear test of the π type circuit . Indeed, the regularity of this line is almost perfect and the joints are tight.

The scheme of the technicql realisation is as follows :

a - Drilling 0.6 mm diameter holes

b - Milling 0.5 mm depth and 1 mm diameter

c - Mounting the assembly finger
soldering ring
copper ring

This is the process used for realizing circuits of the same type on tubes operating at 1,000 Mc/s.

It is not possible to manufacture by this process circular tubes because :

a - drilling from inside towards outside is unfeasible,

b - milling is very difficult to do within 10 cm diameter rings.

On the contrary, in the present state of the technique, this process when applied to a linear tube, appears to permit the obtention of the greatest circuit regularity.

Yet, this solution has not been retained presently for the following reasons :

.../...

a) the first three fingers are not cooled. Now if the circular version gives satisfactory results and demonstrates the necessity of cooling the whole circuit, the linear tube, at least in the conception briefly set forth above, is no longer justified. Besides, the adoption of trapezoidally shaped fingers for a linear circuit would be, of course, meaningless.

b) it would be difficult to maintain the line-sole distance constant within 0.05 mm on a 7 cm length.

In connection therewith it may be noted that the reason a) can be eliminated by the study of a new gun. This study was started recently.

III. STUDY OF NEW CIRCUITS

III.1. Ladder type delay line with alternate fingers

This study, begun during the period covered by the previous report, has been resumed on a line element constituted by 25 fingers. The diameter of the fingers is 4 mm, the pitch 6 mm -see photo 13).

The dispersion curve (Fig. 14) has been plotted according to measurements carried out through three different methods (resonance, mobile short-circuit, mobile probe). The results are in accordance with the statement on this subject in the previous report.

III.2. Oblique ladder type delay line

III.2.1. Principle

It is known that a straight ladder delay line has a pass-band of zero width. If the bars are placed obliquely with respect to the direction of propagation of the beam, the capacities per unity length between the fingers are different on the edges and at the center : the dispersion is no longer vertical.

.../...

III.2.2. Study of the dispersion

For a line of this type one may write, with the same notation as in the previous report (p. 10) :

$$tg^2 \frac{L}{\lambda}\frac{\pi}{2} = \frac{\gamma_{ob} + 4\,\gamma_{1b} \sin^2 \frac{\Psi}{2}}{\gamma_{oc} + 4\,\gamma_{1c} \sin^2 \frac{\Psi}{2}}$$

The experimental determination of the dispersion curve was made with the aid of a line element shown on the photograph of Fig. 15. We have :

- Inclination of the fingers .... 60°
- Finger diameter .... 4 mm
- Finger height .... 10 mm
- Line width .... 34 mm

The measurements are expressed by the curve of Fig. 16. It will be noticed that the pass-band is relatively low (about 10 %).

On the contrary, the coupling resistance must be important and it may be envisaged to operate M type Carcinotrons on the second space harmonic.

Finally, it will be noted that such a structure, having no back-plate is easy to be realized; cooling the fingers would not present any particular difficulty.

-:-:-:-:-:-

PROGRAM OF RESEARCH FOR THE NEXT PERIOD

The realization now being done of two tubes with ladder delay lines, having a ridged back-plate, and trapezoidally shaped fingers cooled by water, will be continued. These tubes will be tested.

Two identical new tubes will be started.

A new gun will be studied in a Carcinotron operating at 1,000 Mc/s.

This study, begun at the end of the period corresponding to the present report, has for its object to permit :

a - the realization of a linear tube the first finger of which will not be cooled.

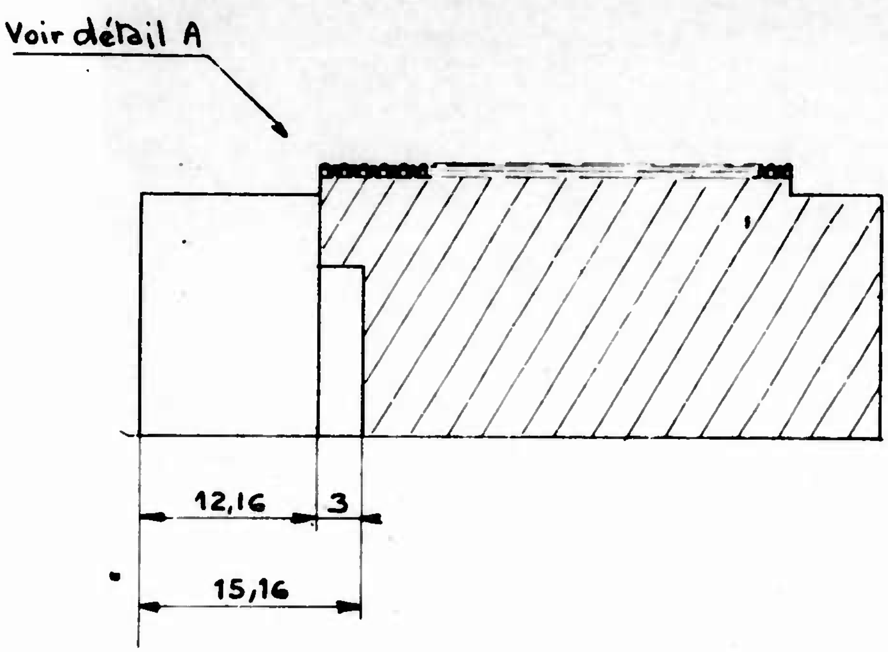
b - connecting two Carcinotrons in series.

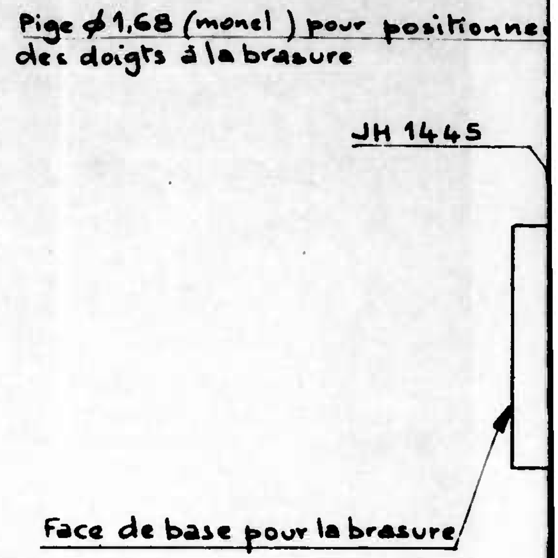
-:-:-:-:-:-

FIGURES

-:-:-:-:-:-

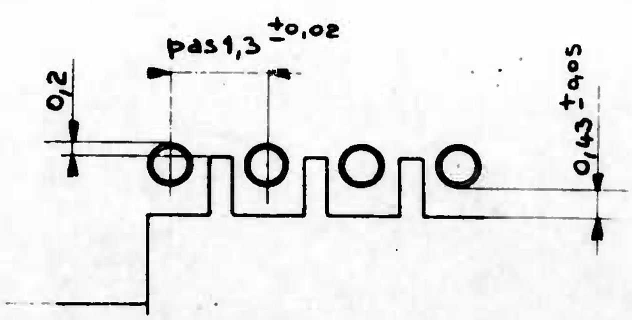
Coupe mn

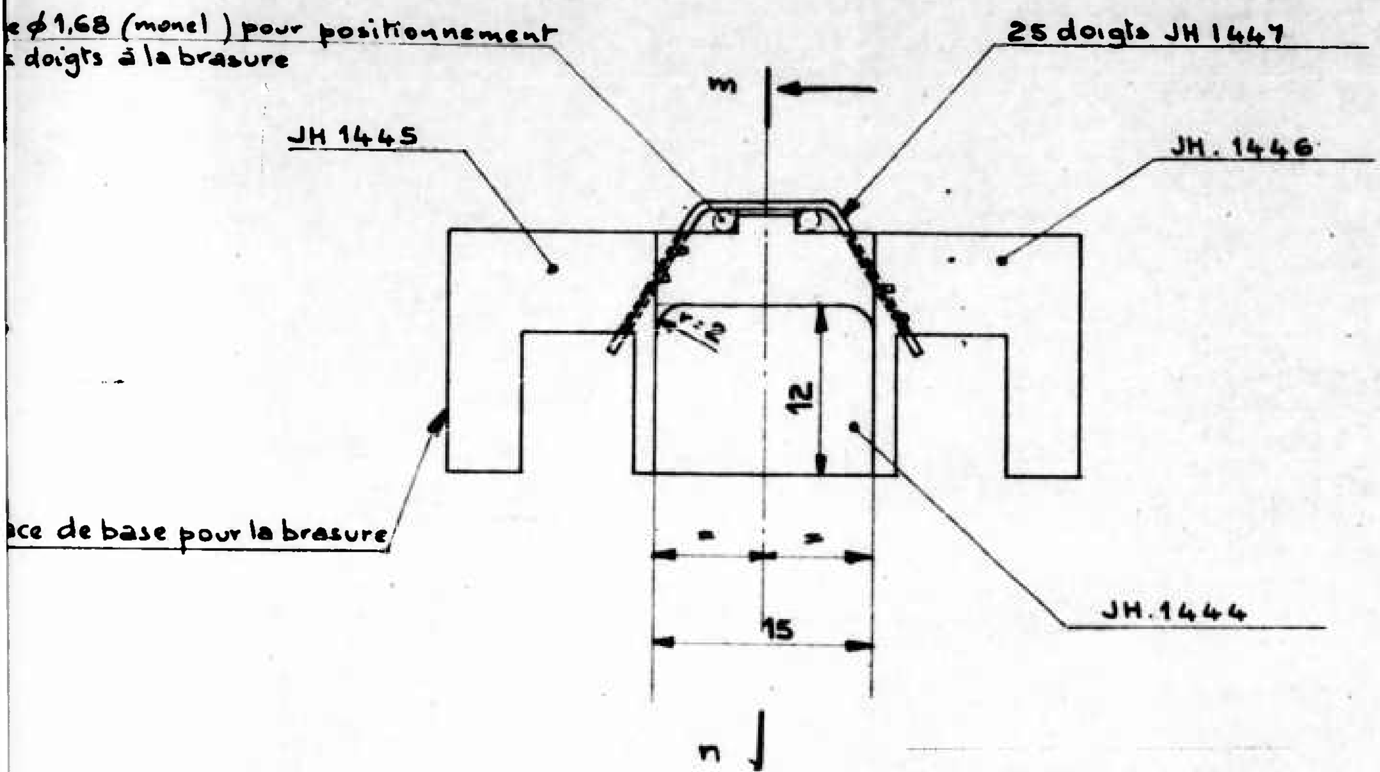




Brasure : A

Détail A - Ech. : 10/1





Brasure : Ag = 685 Cu = 265 Pd = 50

2

Fig. 1

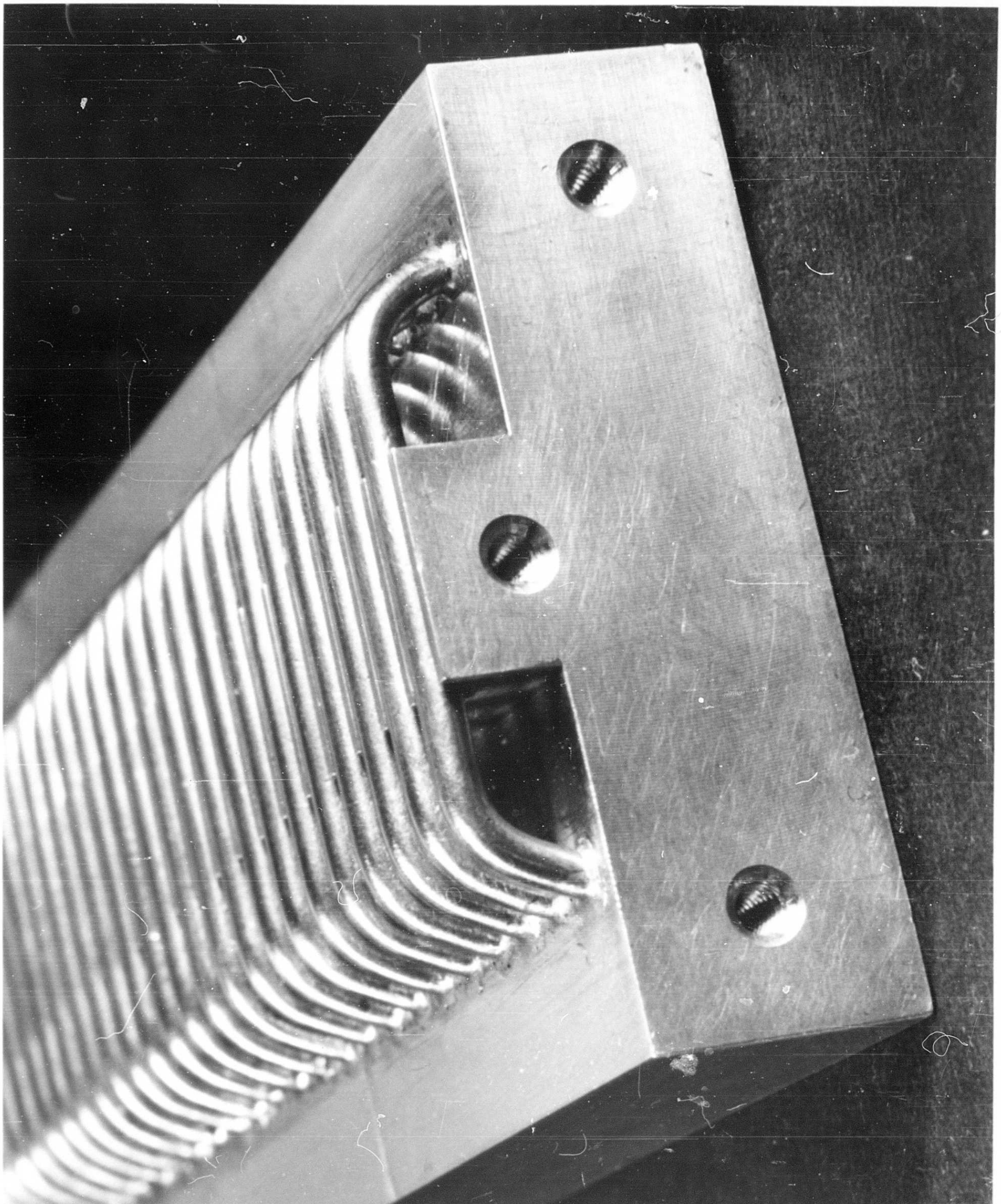
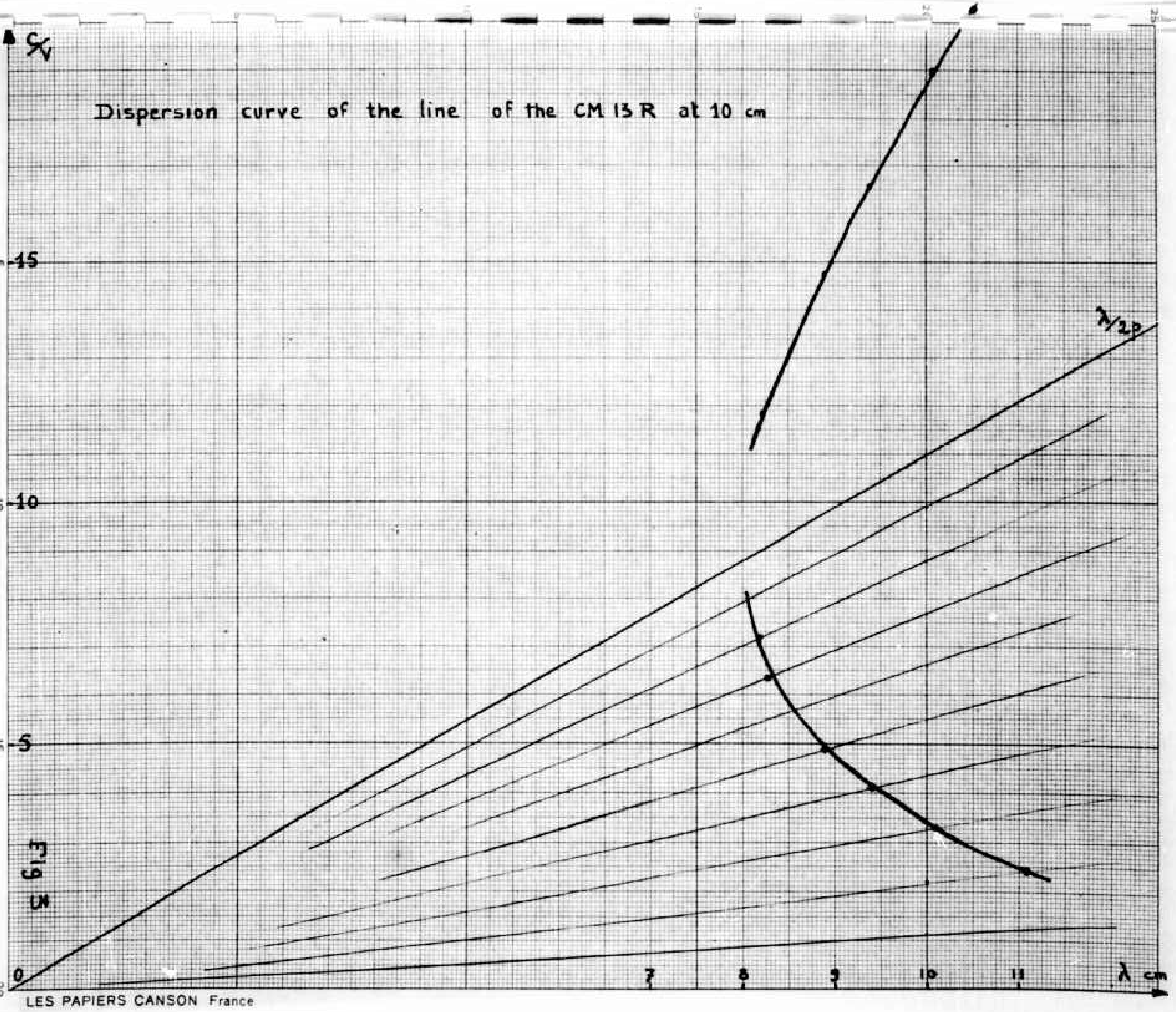


FIG. 2



Dispersion curve of the line of the CM 13 R at 10 cm
c/v
15
10
5
0
λ/2p
7
8
9
10
11
λ cm
LES PAPIERS CANSON France

Fig 3

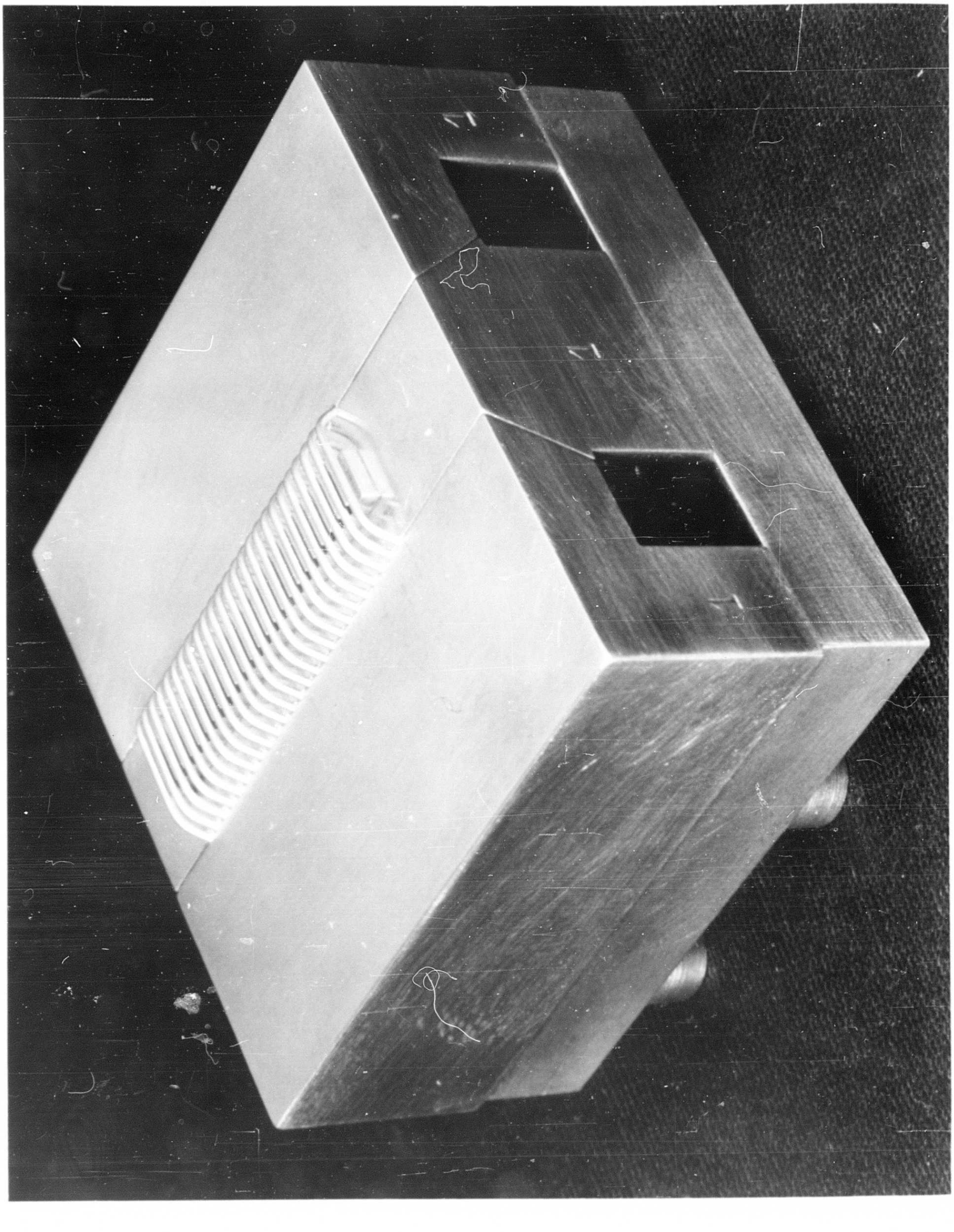


FIG. 4

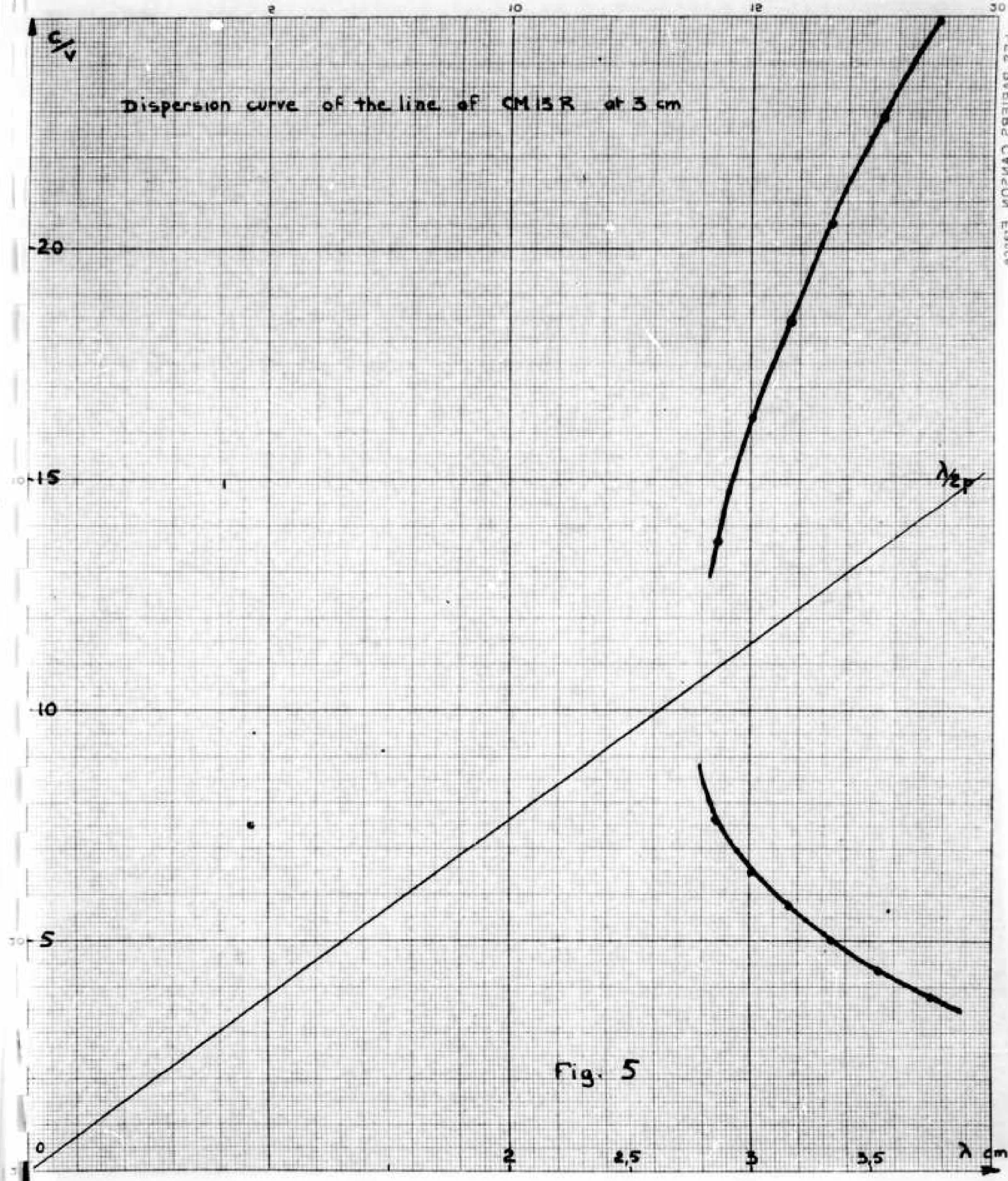

c/v
Dispersion curve of the line of CM 13 R at 3 cm
20
15
10
5
0
λ/2p
2
2,5
3
3,5
λ cm

Fig. 5

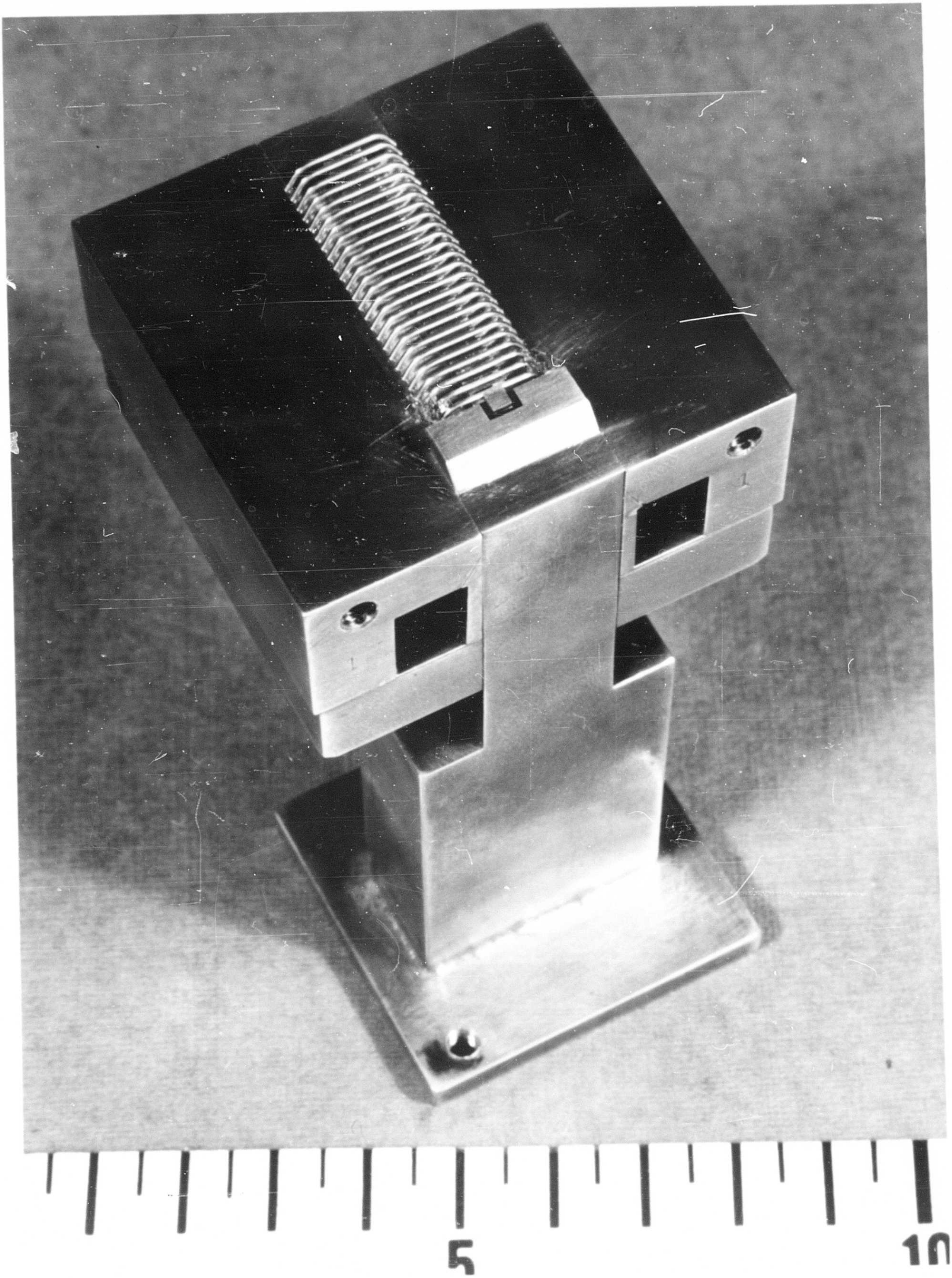


FIG. 6

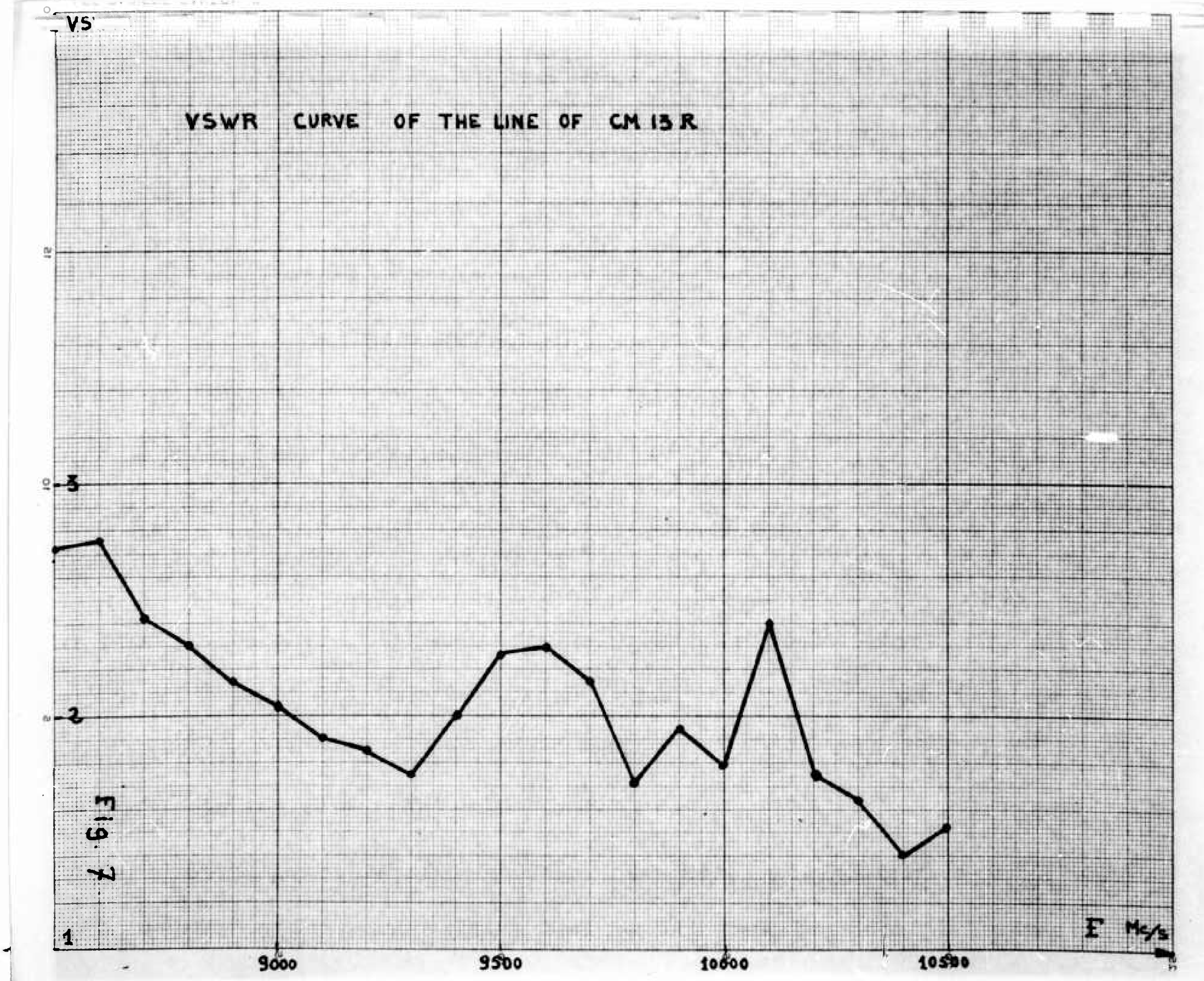

VSWR CURVE OF THE LINE OF CM 13 R
VS
3
2
1
9000
9500
10000
10500
F Mc/s

Fig. 7

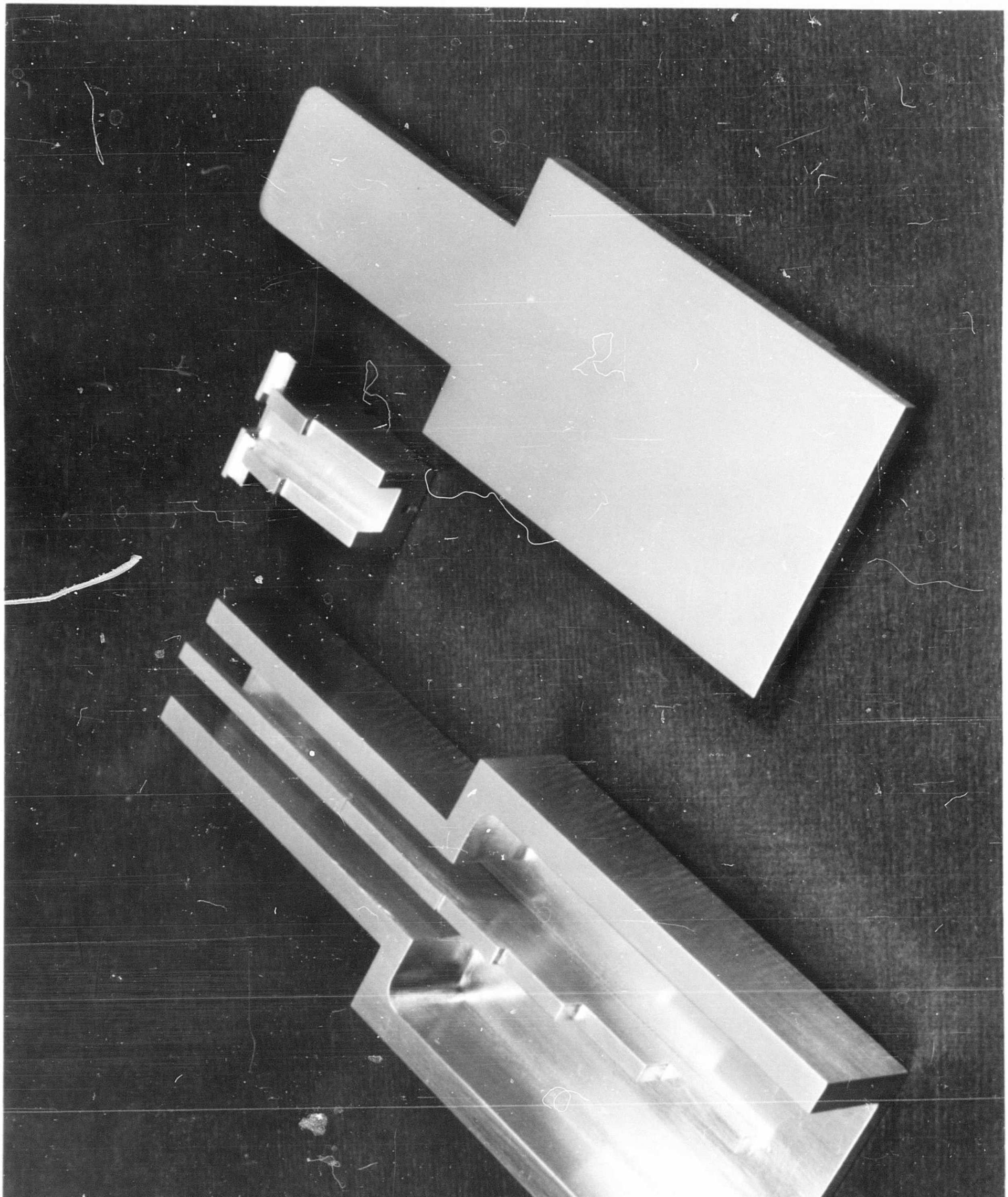


FIG. 8 A

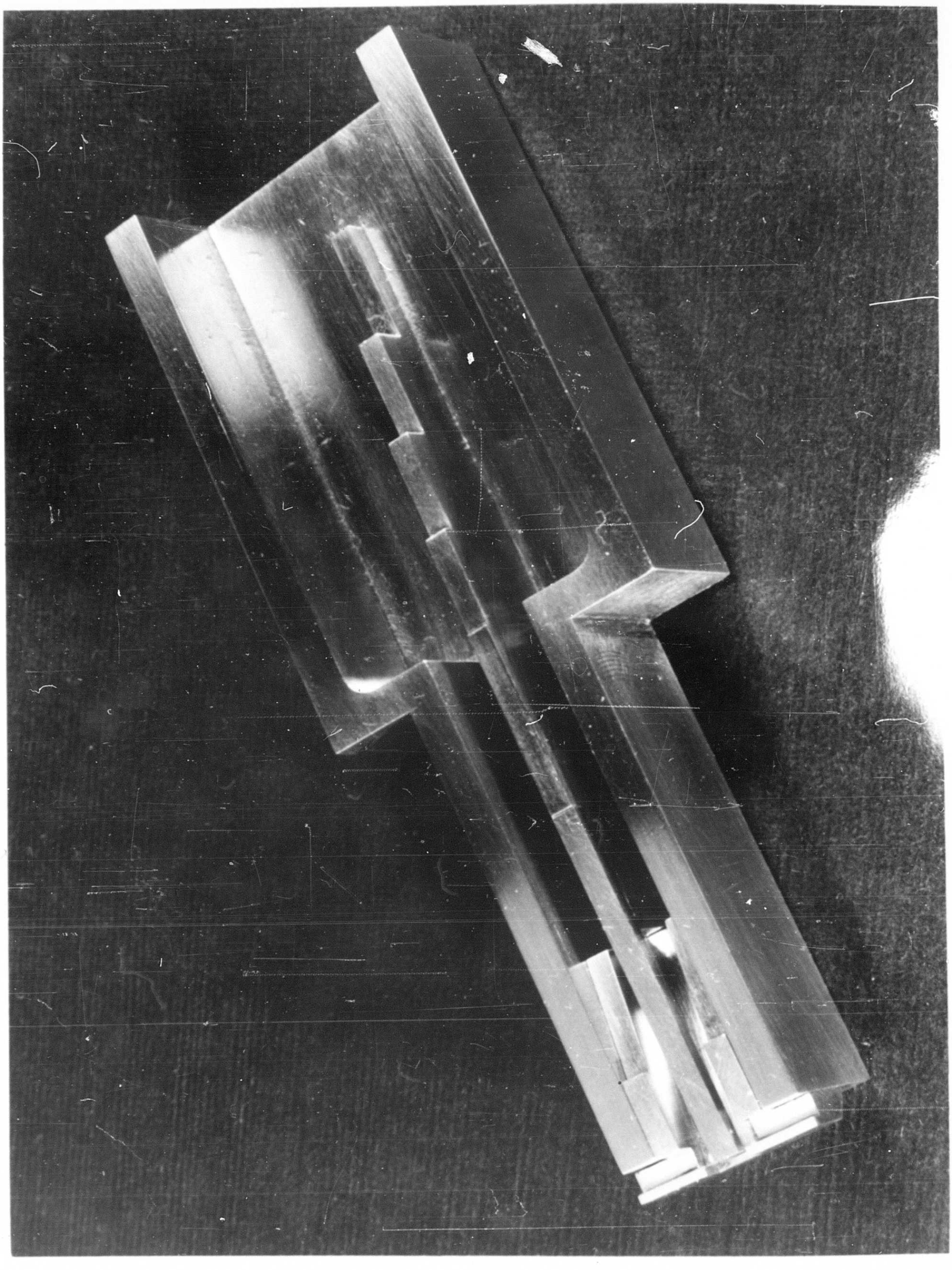


FIG. 8 B

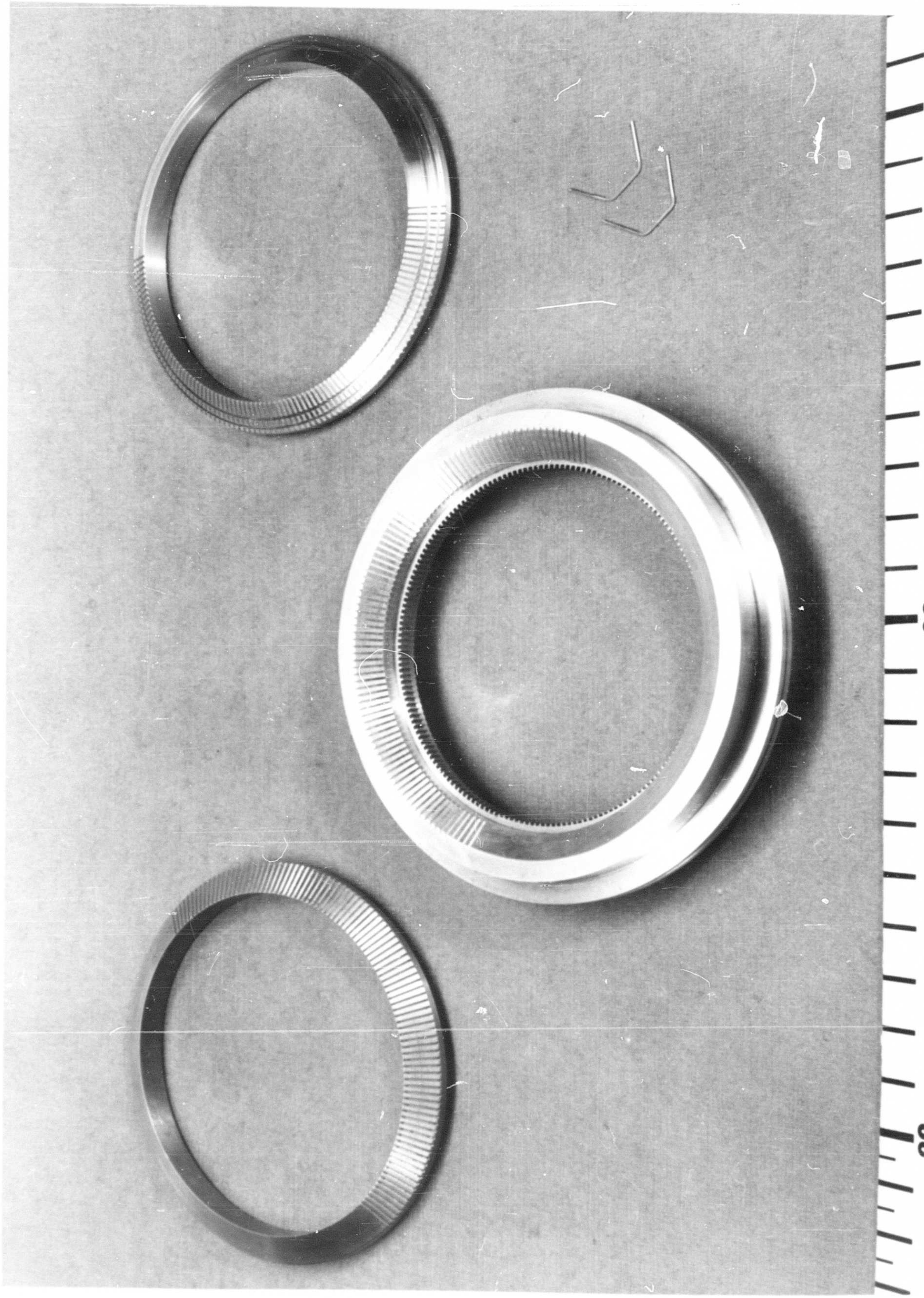
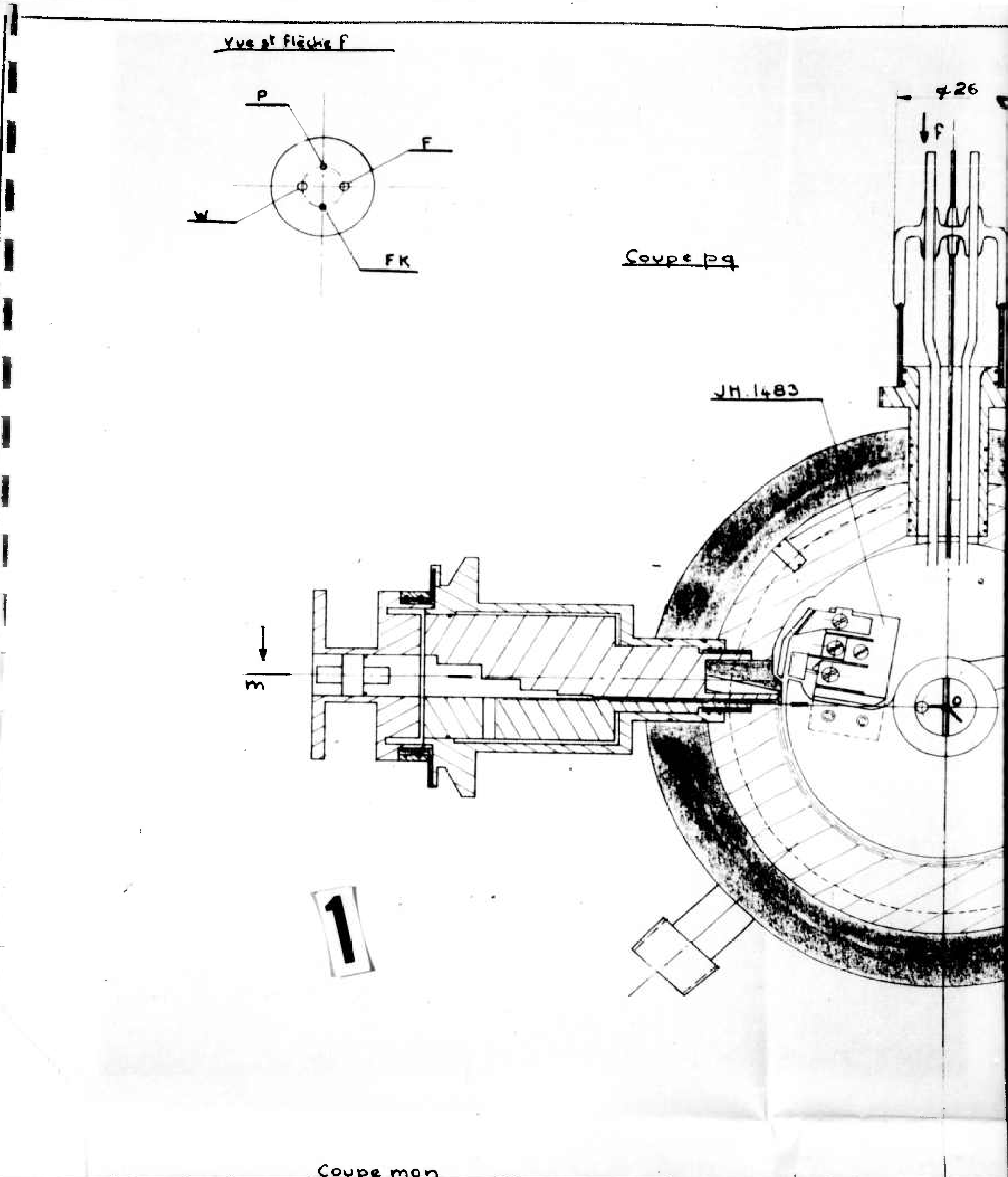
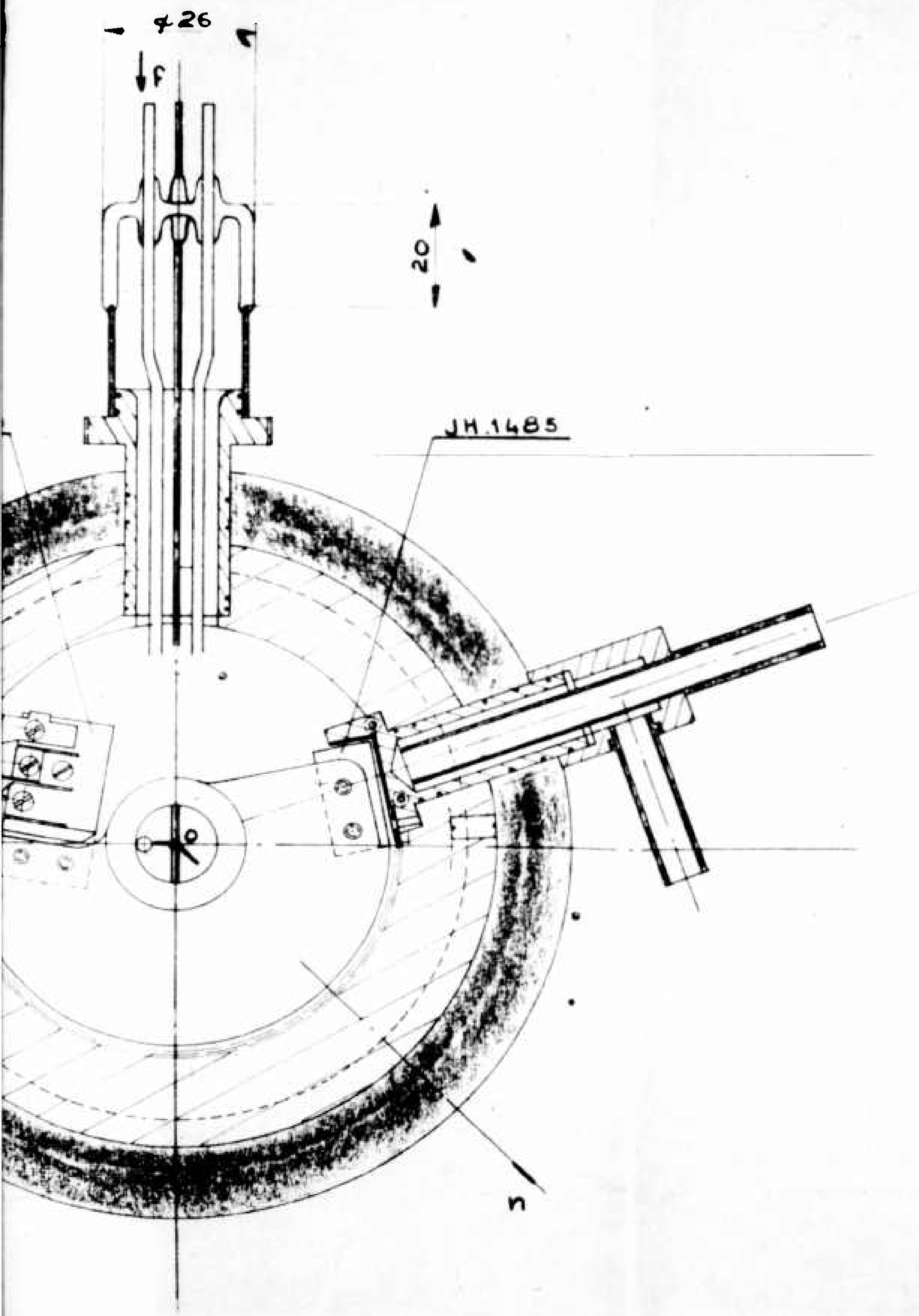


FIG. 9

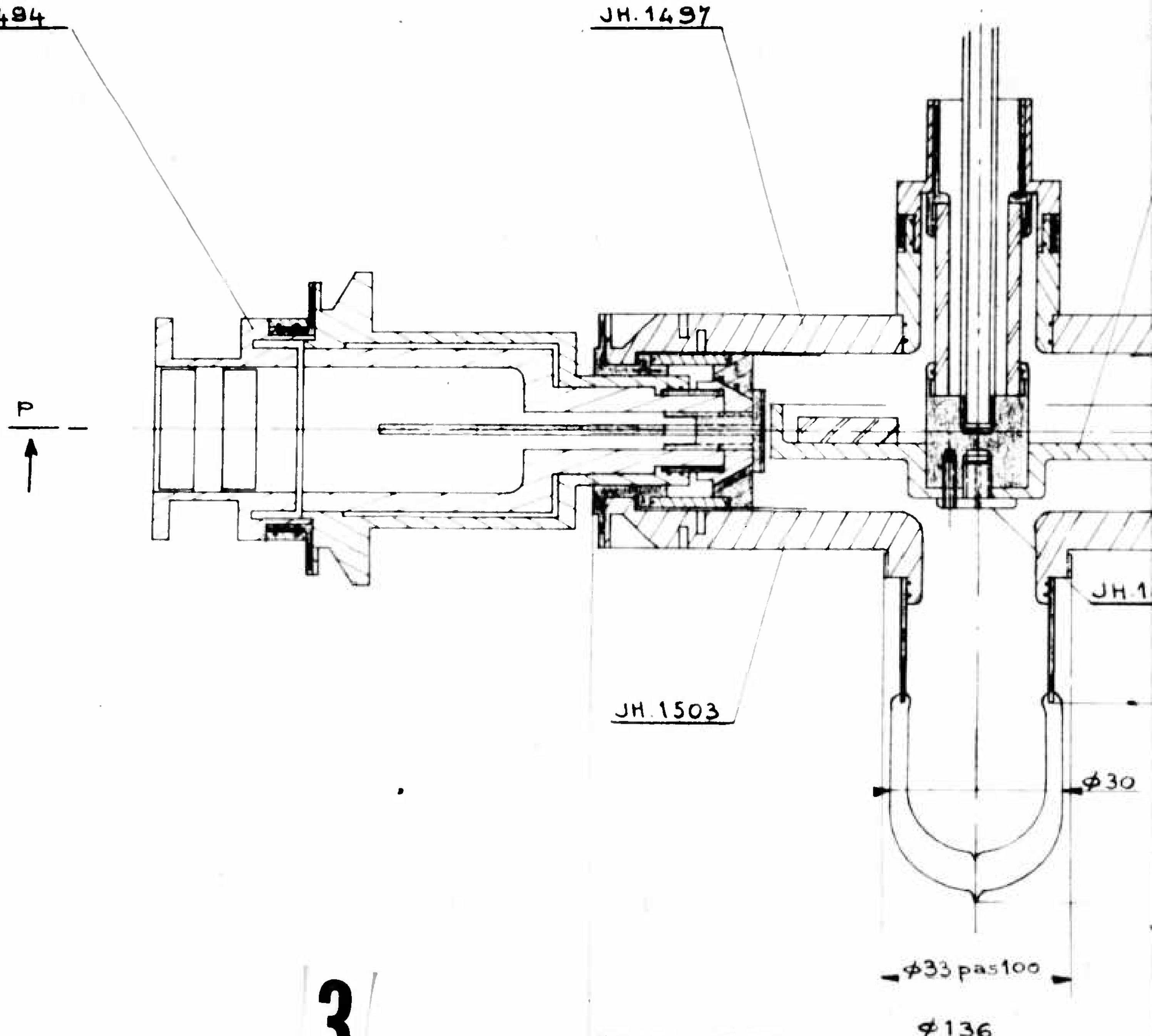


Vue st flèche F
P
F
W
FK
Coupe pq
φ26
F
JH.1483
m
1
Coupe mon

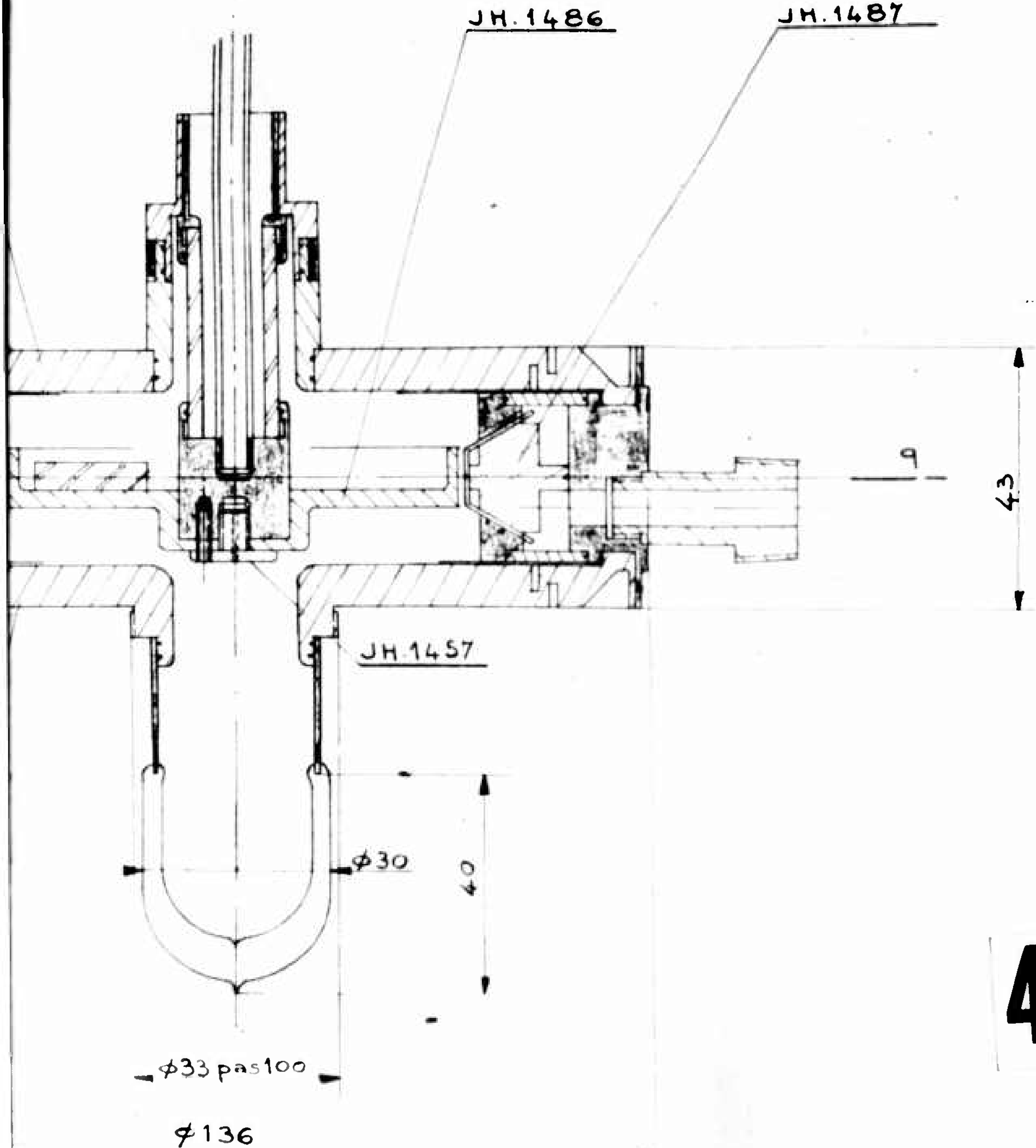


2

Coupe mon



3



4

Fig. 10

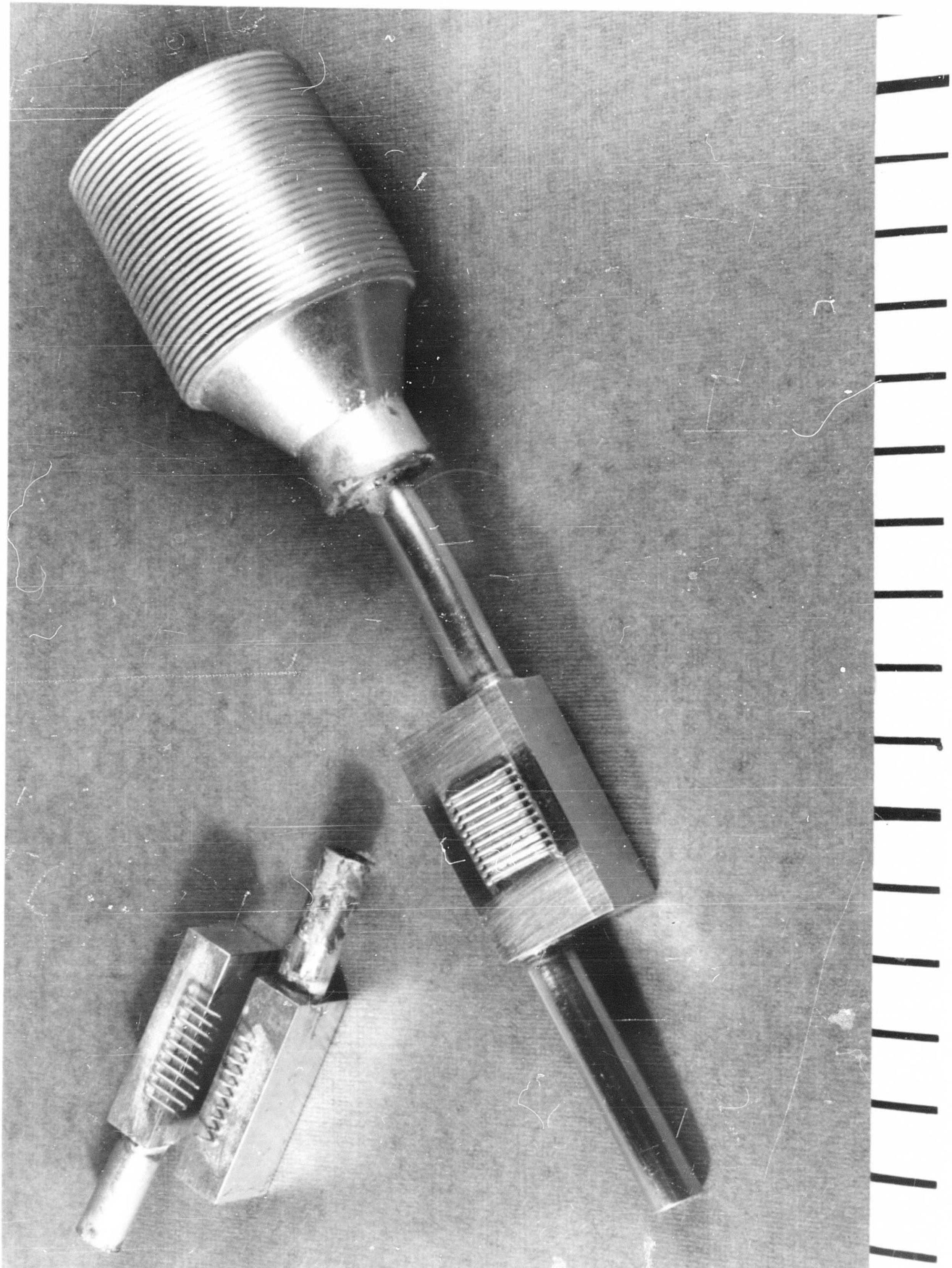


FIG. 1 1

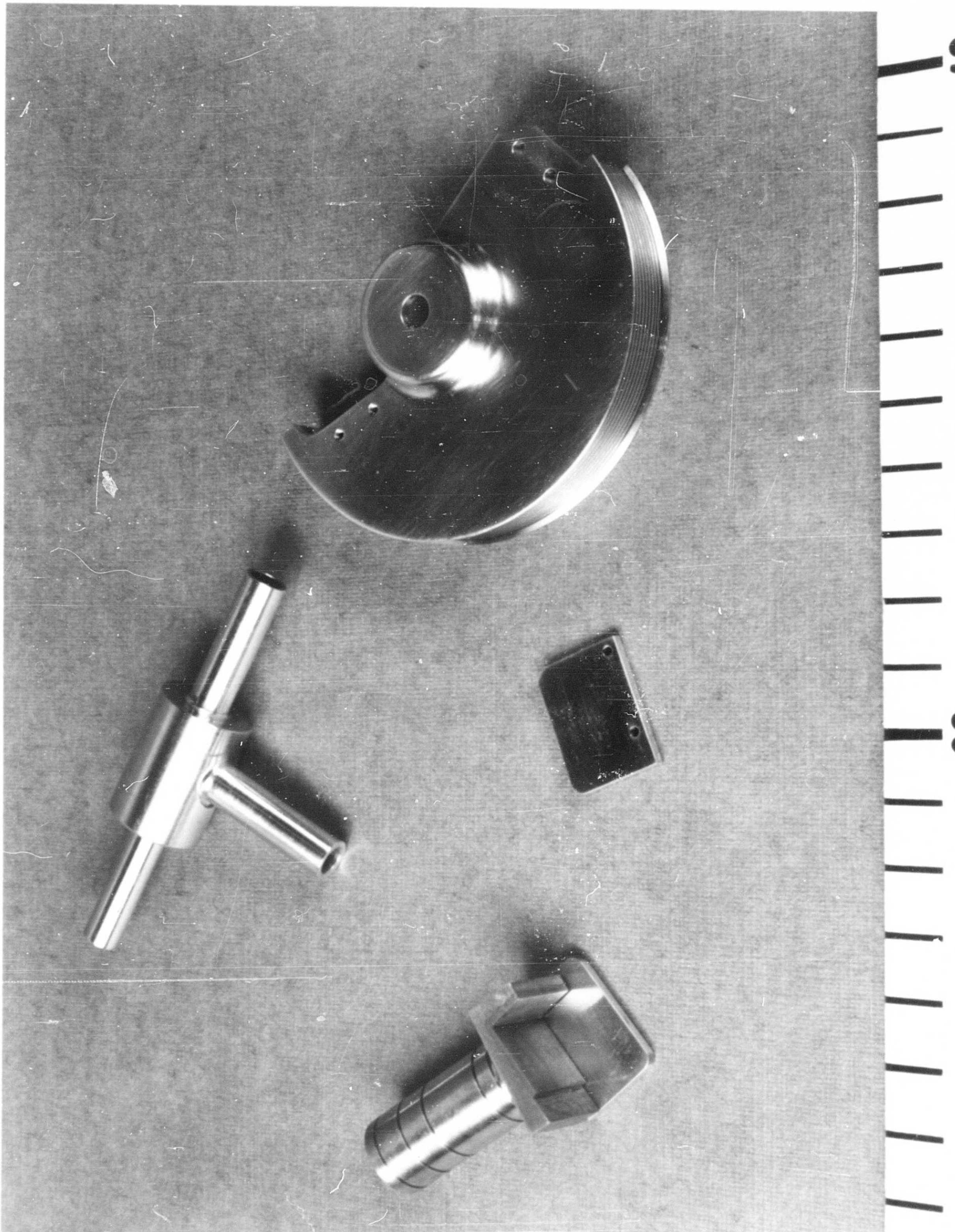


FIG. 12

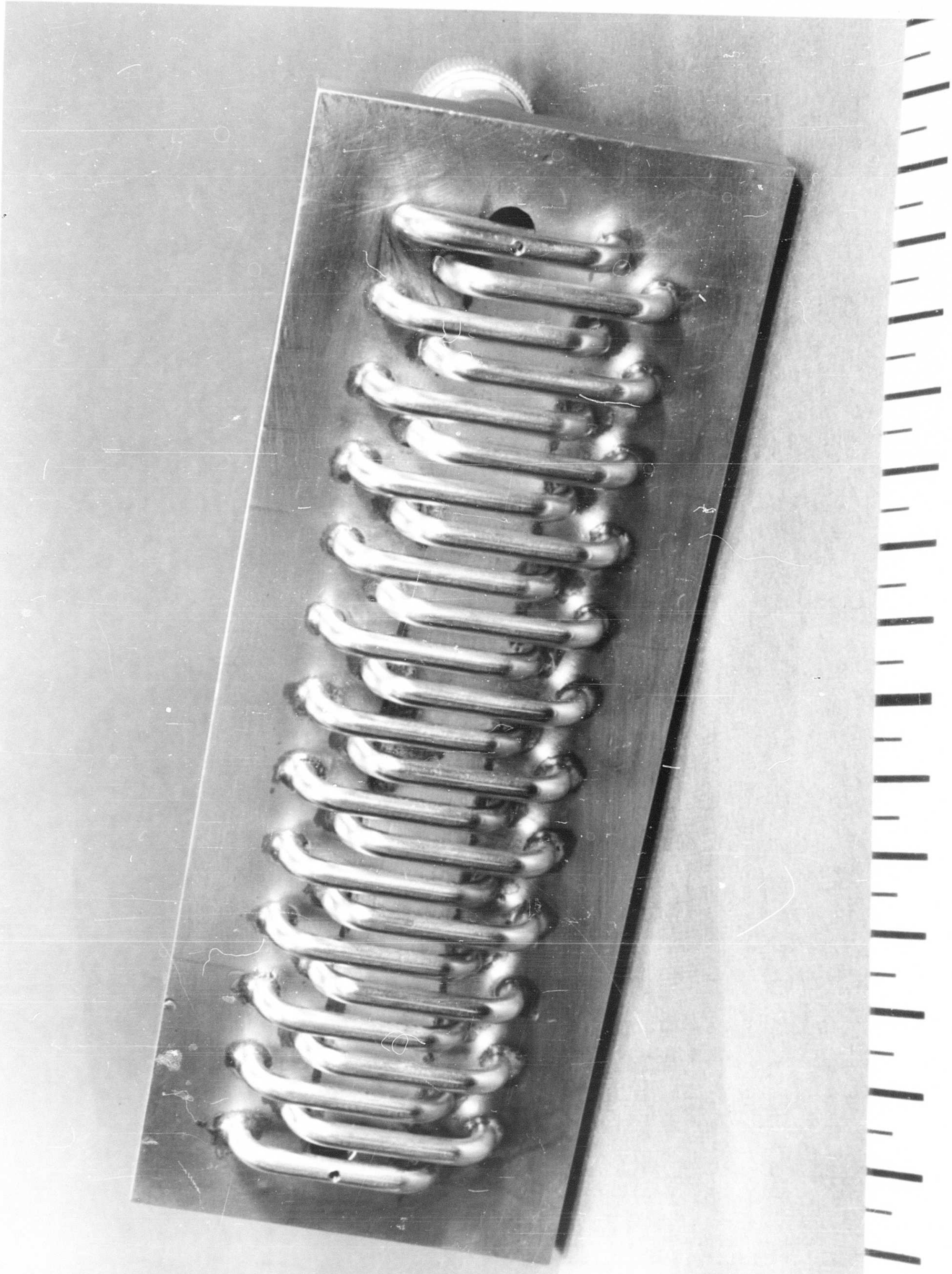
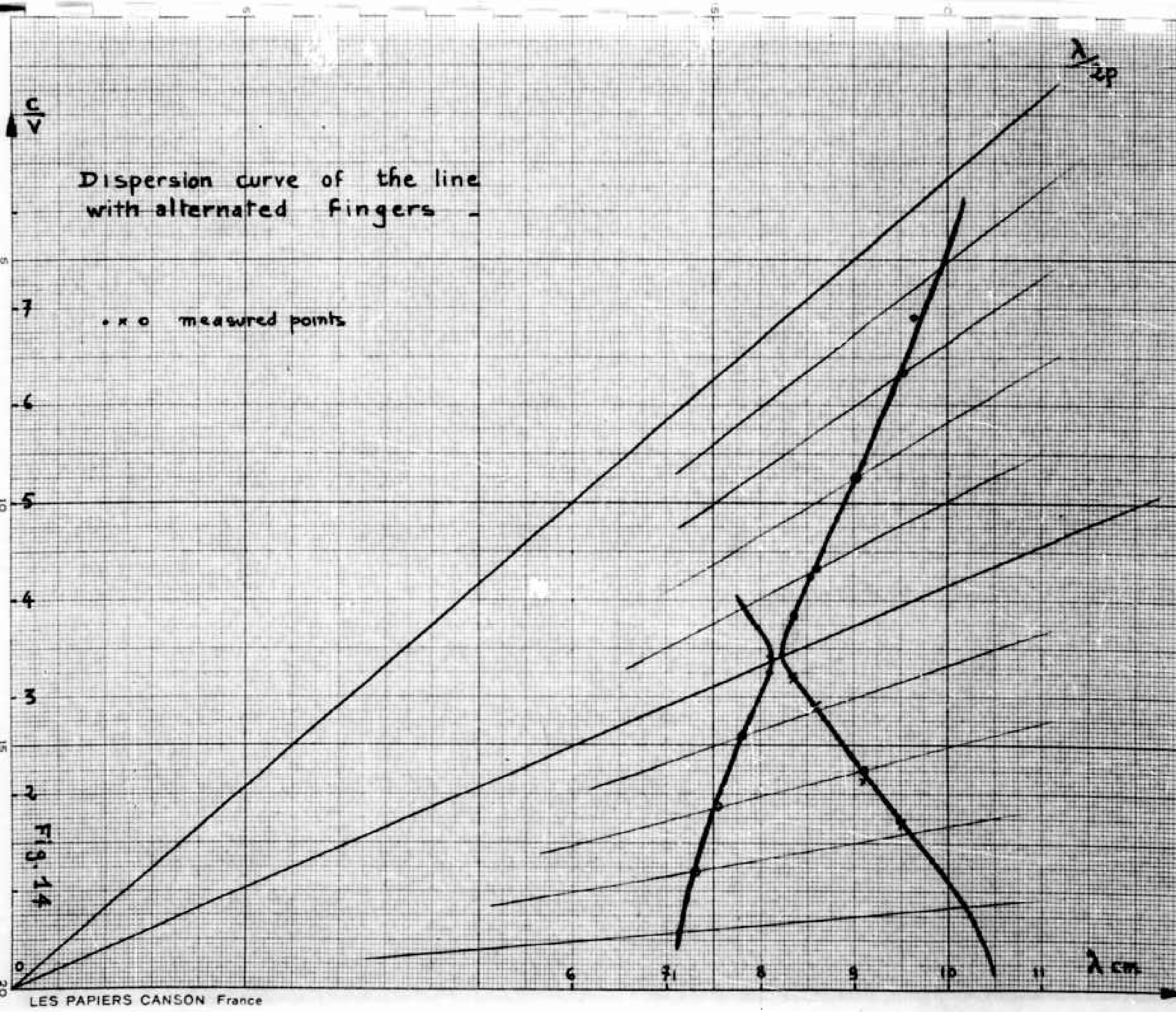


FIG. 13



Dispersion curve of the line with alternated fingers -
• × o measured points
c/v
$\lambda/2p$
λ cm
7
6
5
4
3
2
0
6
7
8
9
10
11
LES PAPIERS CANSON France

Fig. 14

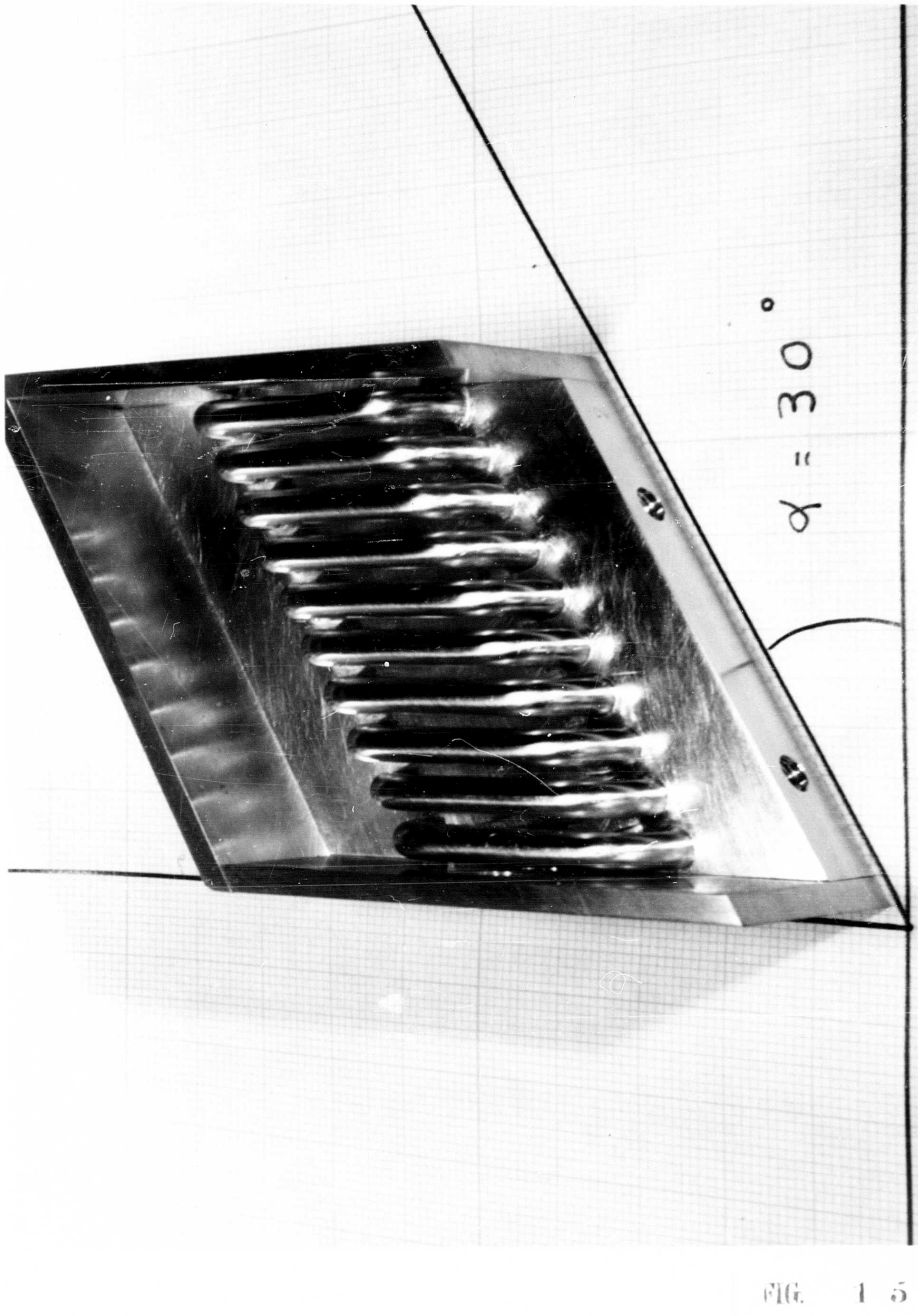


FIG. 15

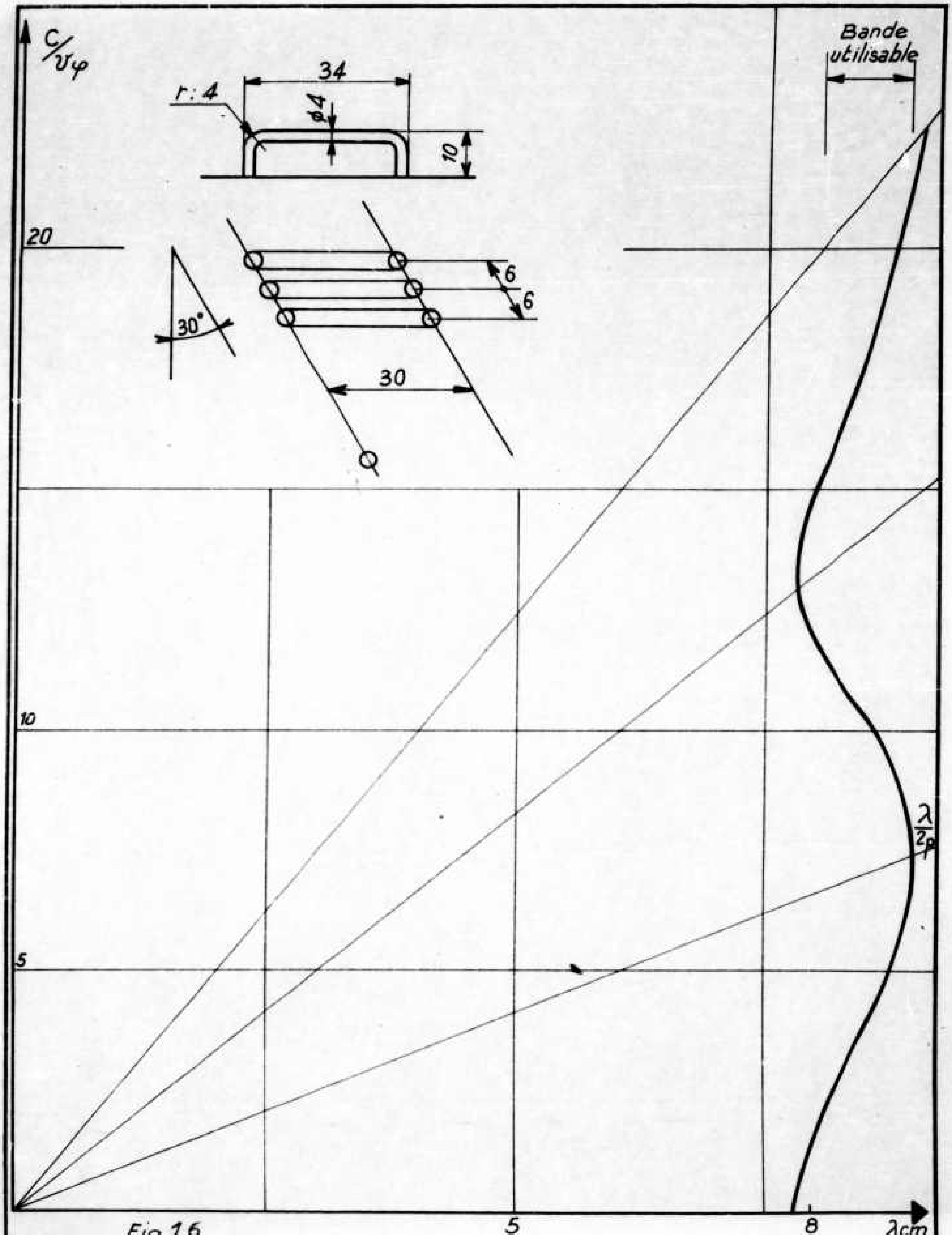


Fig 16

UNCLASSIFIED

UNCLASSIFIED